Appendix B
Vibratory Roller Information

B-1. General

This appendix provides information and guidance concerning modern towed or self-propelled vibratory rollers. Although specifications written after the same fashion as 25 years ago are still usually adequate, evolution has taken place in the capability of the rollers such that specifications should now be written in a somewhat different manner in cognizance of the generally higher operational frequencies and how the roller applies compaction energy to the rock.

B-2. A Typical Former Specification

A vibratory roller specification of the form typically written in the past might have appeared as follows:

Vibratory rollers shall be equipped with a smooth steel compaction drum and shall be operated at a frequency of vibration during compaction operations between 1100 and 1500 vibrations per minute (vpm). Vibratory rollers may be either towed or self-propelled and shall have an unsprung drum weight that is a minimum of 60 percent of the rollers' total static weight. Towed rollers shall have at least 90 percent of their weight transmitted to the ground through the compaction drum when the roller in standing in a vertical position hitched to the towing vehicle. A 10-ton and 15-ton vibratory roller will be required. The 10-ton vibratory roller shall have a minimum static weight of 20,000 pounds, a minimum dynamic force of 40,000 pounds when operating at 1400 vpm, and an applied force of not less than 8,000 pounds per foot of compaction drum length. The 15-ton vibratory roller shall have a minimum static weight of 30,000 pounds, a minimum dynamic force of 50,000 pounds when operating at 1400 vpm, and an applied force of not less than 9,000 pounds per foot of compaction drum length. The level of amplitude and vibration frequency during compaction shall be maintained uniform throughout the embankment zone within which it is operating. Rollers shall be operated at speeds not to exceed 1.5 miles per hour. The equipment manufacturer shall furnish sufficient data, drawings, and compaction for verification of the above specifications. The character and efficiency of this equipment shall be subject to approval of the Contracting Officer.

B-3. Vibratory Roller Variables

The centrifugal force applied by a vibratory roller is a function of amplitude, unsprung drum weight, and vibrating frequency as follows:

$$\text{Centrifugal Force} = \frac{A \times W_u \times (VPM)^2}{35198} \qquad \text{(B-1)}$$

where:

A = Amplitude = The distance the drum lifts of the ground or surface

W_u = Unsprung drum weight = Weight of the drum and internal works only. Does not include frame, brackets, etc.

VPM = Vibrating Frequency = The number of times the drum lifts of the ground in a given minute

The constant 35198 is derived for dimensional consistency as:

$$C = \frac{g \times 60^2}{4\pi^2} \qquad \text{(B-2)}$$

where:

g = acceleration due to gravity = 385.6 inches per sec^2

π = 3.14

Studies of impact spacing and force have resulted in the designation of 6 to 8 impacts per lineal foot of roller travel as minimum criteria for effective compaction. The number of roller impacts (lifting/falling of the drum) depends upon the vibrating frequency versus the speed of operation of the roller as follows:

$$\text{Impacts per foot} = \frac{VPM}{\text{speed of the roller, ft/min}} \qquad \text{(B-3)}$$

Table B-1 shows the impact spacing per foot for VPM versus roller speed.

Table B-1
Vibratory Rollers, Impact Spacing Per Foot

VPM	Rolling Speeds						
	1 mph	1.5 mph	2 mph	2.5 mph	3 mph	3.5 mph	4 mph
1200	13.6	9.1	6.8	5.5	4.5	3.9	3.4
1300	14.8	9.8	7.4	5.9	4.9	4.2	3.7
1400	15.9	10.6	7.9	6.4	5.3	4.5	4.0
1500	17.0	11.4	8.5	6.8	5.7	4.8	4.3
1600	18.2	12.1	9.0	7.2	6.0	5.2	4.5
1700	19.3	12.9	9.6	7.7	6.4	5.5	4.8
1800	20.4	13.6	10.2	8.2	6.8	5.8	5.1
1900	21.6	14.4	10.8	8.6	7.2	6.2	5.4
2000	22.7	15.2	11.4	9.1	7.6	6.5	5.7
2100	23.9	15.9	11.9	9.6	8.0	6.8	6.0
2200	25.0	16.7	12.5	10.0	8.3	7.1	6.2
2300	26.1	17.4	13.1	10.5	8.7	7.5	6.5
2400	27.3	18.2	13.6	10.9	9.1	7.8	6.8
2500	28.4	18.9	14.2	11.4	9.5	8.1	7.1

The total applied force (referred to as the dynamic force in the older specification of paragraph B-2) is the sum of the unsprung drum weight and the centrifugal force. Considering the 10-ton vibratory roller of paragraph B-2, the unsprung drum weight had to be at least 60 percent of 20,000 pounds or 12,000 pounds. Deducting that 12,000 pounds from the minimum required total applied force (minimum dynamic force) of 40,000 pounds at 1400 vpm results in a centrifugal force of 28,000 pounds at some amplitude, A. Using equation B-1, the required amplitude can be calculated as:

$$28{,}000 \text{ lb.} = \frac{A \times 28{,}000 \text{ lb.} \times 1400^2 \; vpm}{35198} \qquad \text{(B-4)}$$

or:

$$A = 0.04 \text{ inches}$$

Using this amplitude, the range in centrifugal force allowed by the specification of paragraph B-2 by allowing vibration frequency to range between 1100 vpm and 1500 vpm can be calculated again from equation B-1 as:

$$CF_{1100} = \frac{(.04)(12{,}000)(1100^2)}{35198} = 16{,}500 \text{ lb.}$$

$$CF_{1500} = \frac{(.04)(12{,}000)(1500^2)}{35198} = 30{,}680 \text{ lb.}$$

and, adding the roller unsprung weight to each for total applied force, it is seen that the older specification version permitted that number to range from 28,500 pounds to 42,680 pounds which is a very wide range in applied compactive effort indeed. Since the applied force had to also be at least 8,000 pounds per foot of drum length, the 10-ton roller could vary in length from 3.6 ft long at 1100 vpm to 5.3 ft long at 1500 vpm. If that roller was operating at 1100 vpm at 1.5 mph, the impacts per lineal foot of travel would be 1100 vpm/(88 ft/min × 1.5 mph) = 8.3. If the roller was operating at 1500 vpm, the impacts per foot would be 1500vpm/(88 ft/min × 1.5) = 11.4. So, the older specification would generally suffice but leave considerable room in the compactive effort delivered.

B-4. A Recent Specification

The roller considerations for Seven Oaks Dam accommodated the modern roller capabilities such that the equipment specifications used there were as follows:

Vibratory rollers used for compacting filter, rock transition, rockfill, alluvial transition, shell, and rock toe material shall be equipped with a smooth steel compaction drum and may be either towed or self-propelled. Towed rollers shall have at least 90 percent of their weight transmitted to the ground through the compaction drum when the roller is standing in a level position hitched to the towing vehicle. A 10-ton and 15-ton vibratory roller will be required. The 10-ton vibratory roller shall have a minimum static weight of 20,000 pounds and be capable of delivering a total applied force of not less than 8,000 pounds per foot of drum width, but not to exceed 9,000 pounds per foot of drum width. The 15-ton vibratory roller shall have a minimum static weight of 30,000 pounds and shall be capable of delivering a total applied force of not less than 10,000 pounds per foot of drum width. The total applied force shall be the sum of the centrifugal force and the drum module weight. The level of amplitude and vibration frequency during compaction shall be maintained uniform throughout the embankment zone within which it is operating. Rollers shall be operated at speeds which will result in a minimum of 10 impacts per foot of roller travel. The equipment manufacturer shall furnish sufficient data, drawings, and compaction for verification of the above specifications. The character and efficiency of this equipment shall be subject to the approval of the Contracting Officer.

It is apparent that this specification establishes the compactive effort as a minimum value and allows the maximum speed of operation for cost efficiency in fill operations.